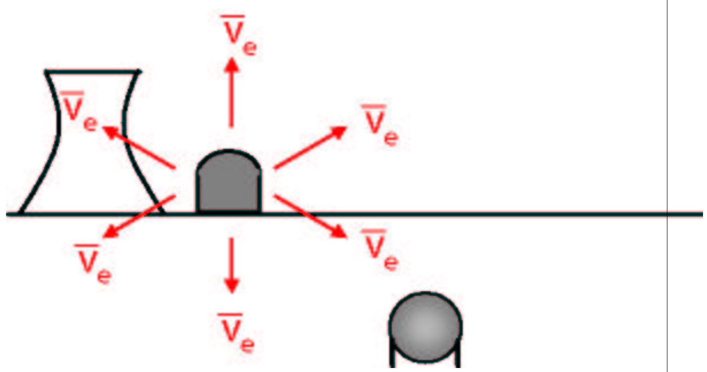
Going beyond θ_{13}:
A whole new angle on reactor studies



- The idea for the experiment
- The sensitivity to Beyond-Standard-Model Physics
- Experimental Issues

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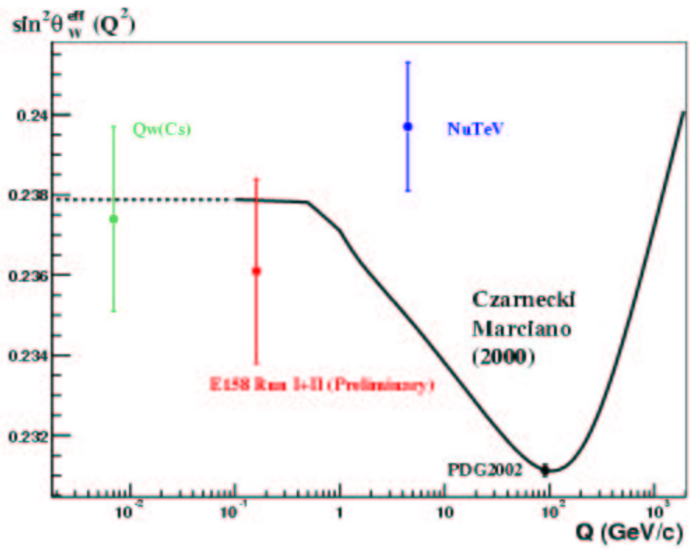
(with input from J. Formaggio, J.Link, M. Shaevitz)
see hep-ex/0403048



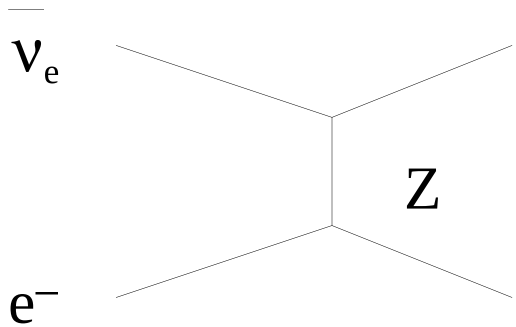
Standard
Model
Prediction

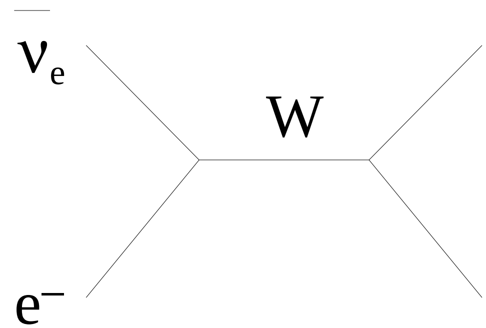
A reactor-based $\sin^2\theta_W$ measurement:

- Probes new physics in the neutrino sector (like NuTeV)
- Has low $Q^2 \sim$ 4E-6 GeV^2
- Has different systematics from NuTeV

How to measure $\sin^2\theta_W$ at a reactor:

Use the antineutrino-electron **elastic scattering** (ES)





$$\frac{d\sigma}{dT} = \frac{G^2 m}{2\pi}\left\{(C_V+C_A)^2 + (C_V-C_A)^2\left(1-\frac{T}{E}\right)^2 + (C_A^2-C_V^2)\, m\,\frac{T}{E^2}\right\}$$

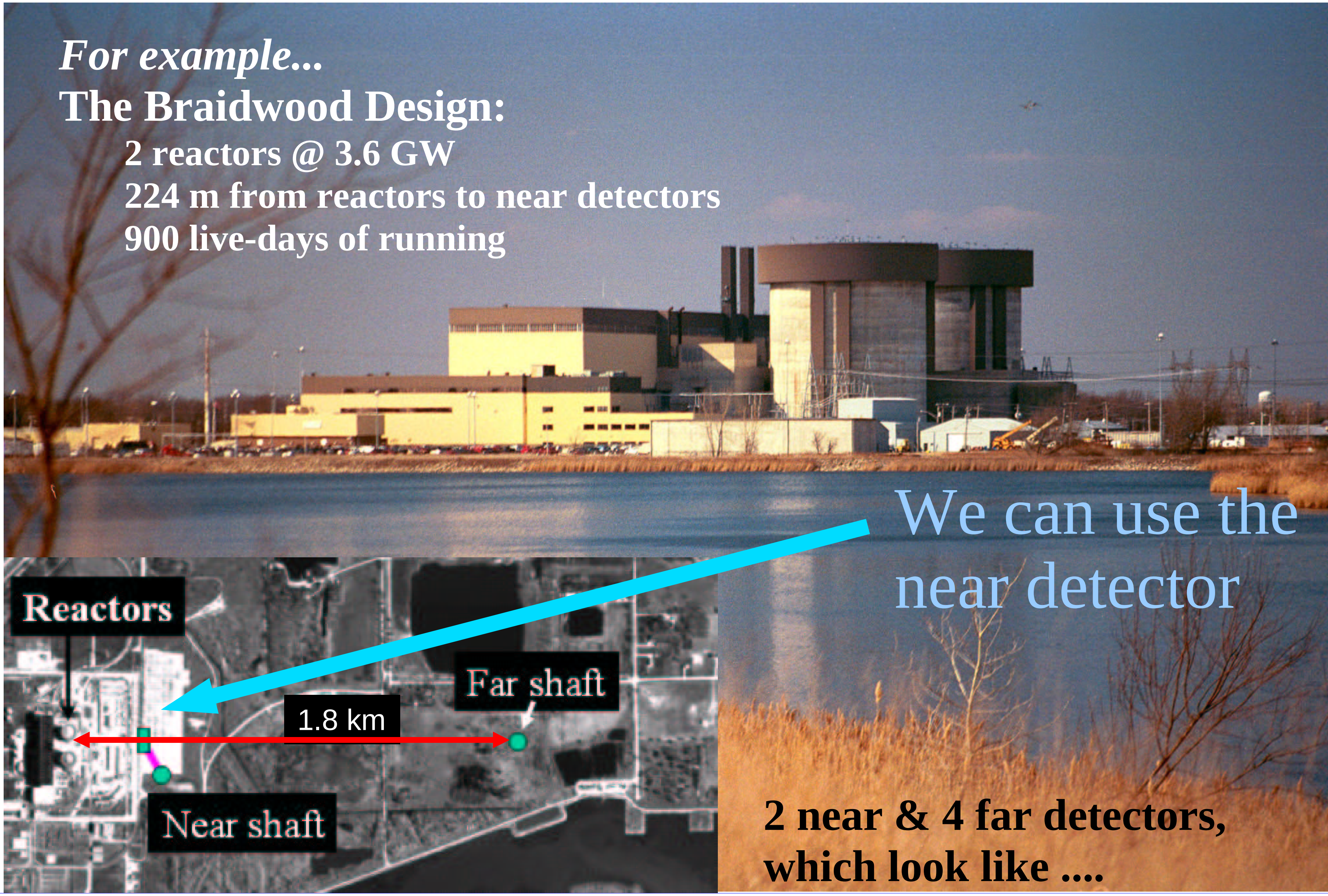
$$C_V = \tfrac{1}{2} + 2\sin^2\theta_W$$

$$C_A = -\tfrac{1}{2}$$

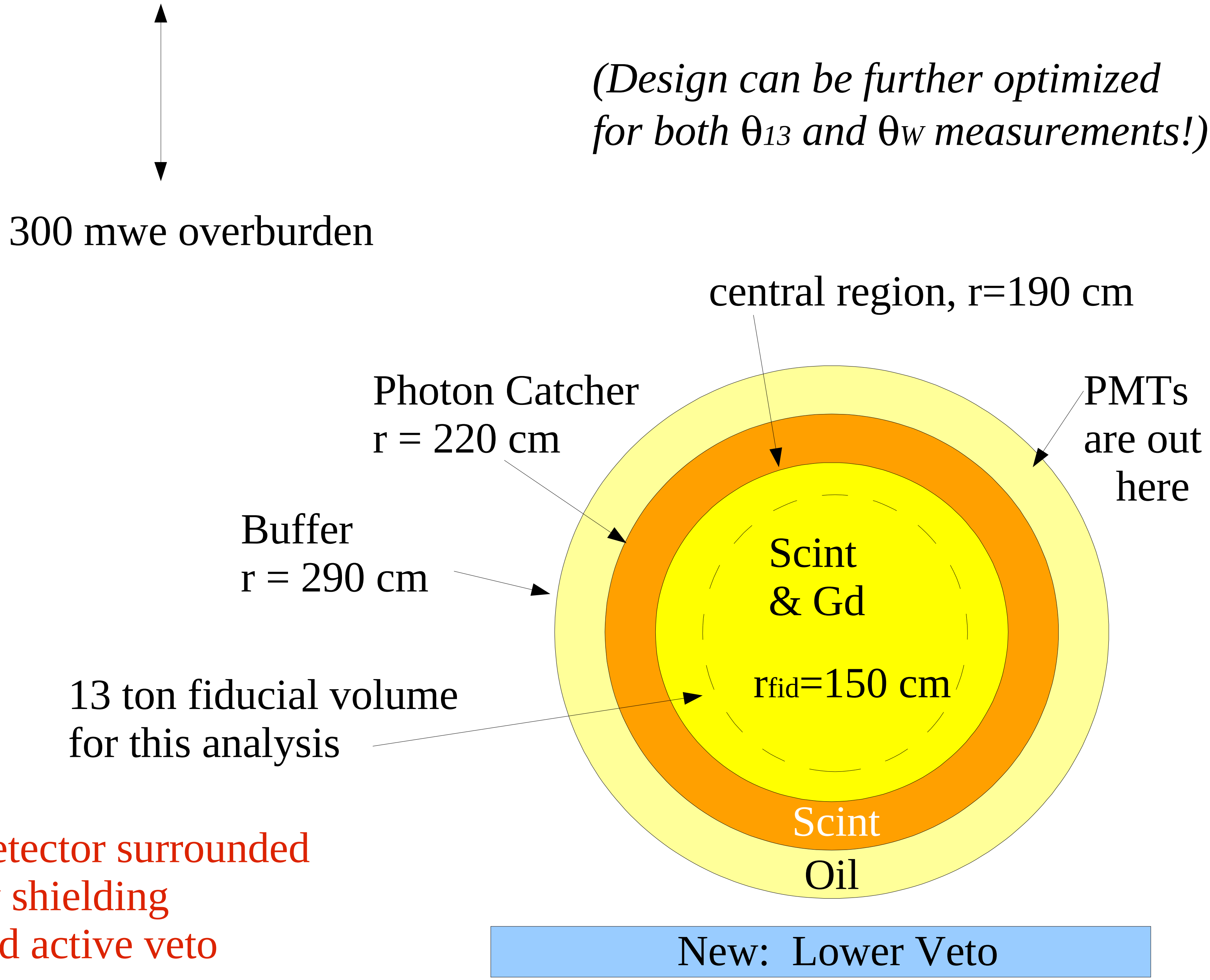
T = electron KE energy
E = neutrino energy
m= mass of electron
This assumes $\mu_\nu=0$

The total rate for this process is sensitive to $\sin^2\theta_W$

There are already people who would like to do a reactor experiment
With goal of measuring osc. mixing parameter θ_{13} (at atmospheric Δm^2)



(Design can be further optimized for both θ_{13} and θ_W measurements!)



Detector surrounded
by shielding
and active veto

A sensible range to consider for the measurement is:

dN/N	= 1.3%.......	We can do that
	= 1.0%.......	May be attainable
	= 0.7%......	Hard!

$$\boxed{dN/N=1.3\% \;\Leftrightarrow\; d(\sin^2\theta_W)=\pm 0.0019}$$

Compare to NuTeV: ±0.0017

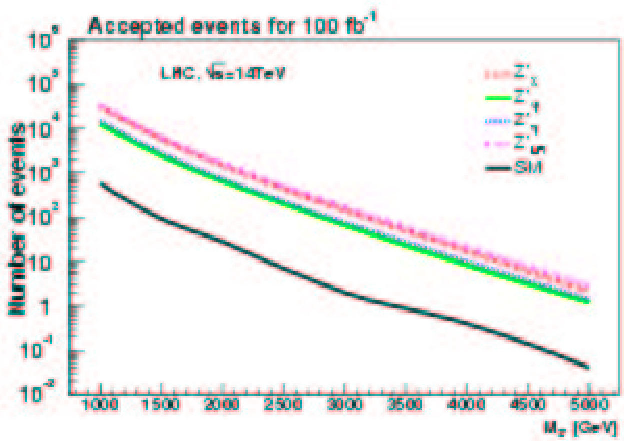
Is this range interesting for Beyond Standard Model physics?

Sensitivity to a heavy Z'

Using SO(10) Zχ as an example (Marciano)

Need dN/N~0.5% for 800 GeV (@ 90% CL)

1.0% for 566 GeV



Can reach above present limits (just!)

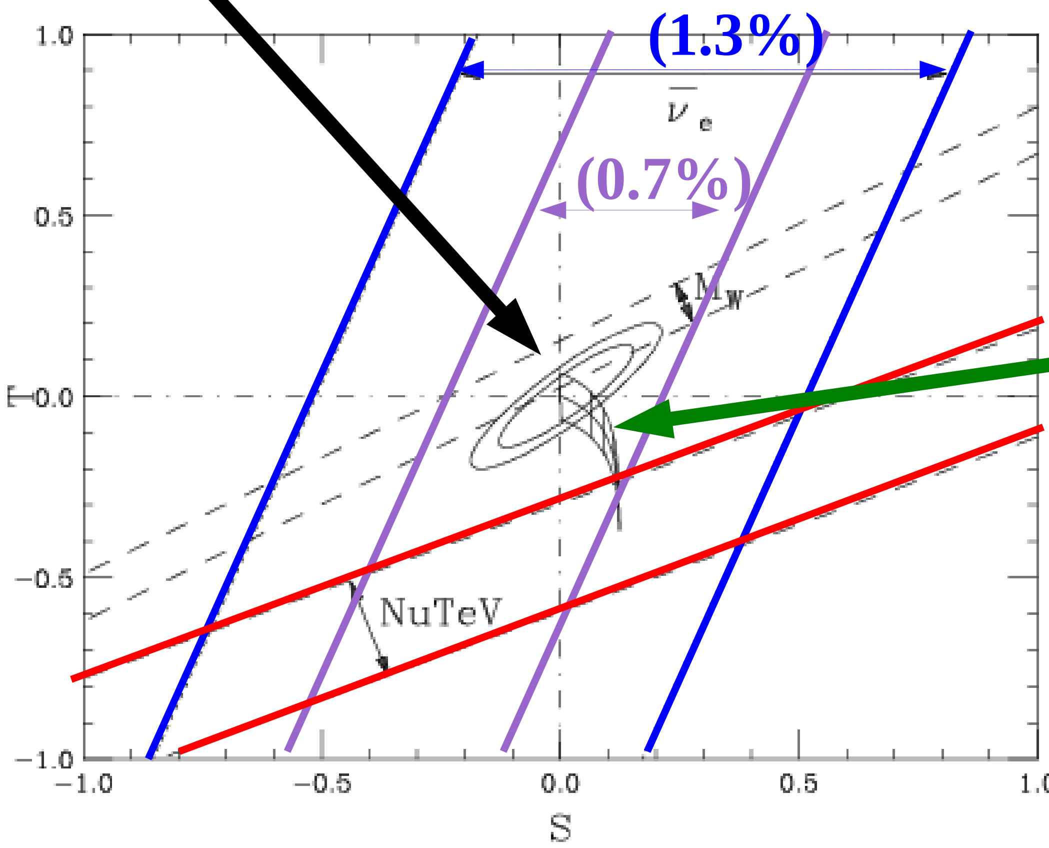
Hard to imagine competing with LHC!

Sensitivity to S and T

See Rosner, hep-ph/0404264

Fit which does not include NuTeV and uses a light Higgs...

Unusual in strong S-dependence



indicates Higgs dependence

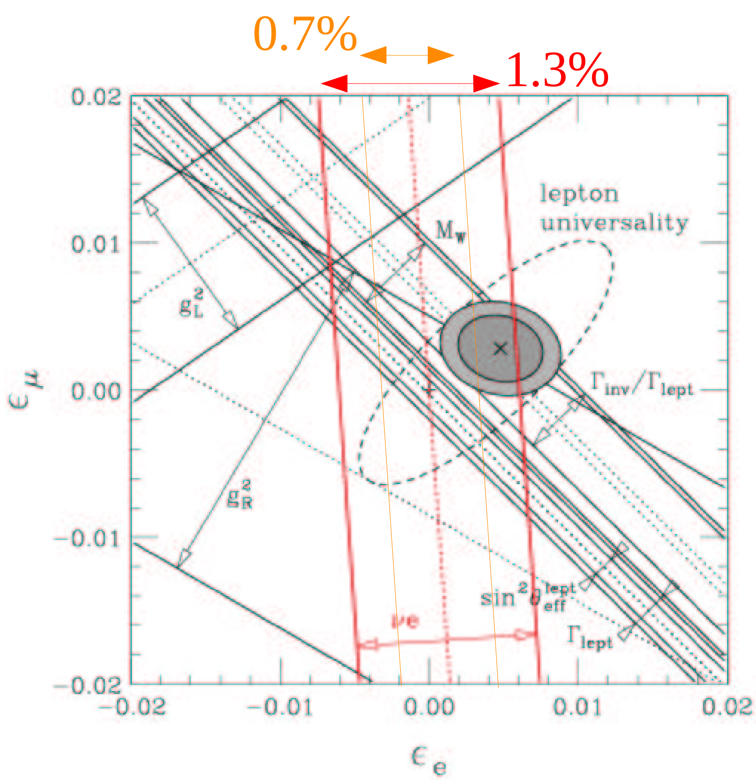
Sensitivity to ε

(see Loinaz et al, hep-ph/0403306)

A better fit is obtained if neutrinos are allowed to have non-standard couplings (adjusted by $\varepsilon \sim 0.3\%$)

$Z\nu\nu \leftrightarrow (1-\varepsilon)$
$W\ell\nu \leftrightarrow (1-\varepsilon/2)$

Idea has now been expanded to consider flavor dependence, with fits to world's data on lepton couplings...



Reactor experiment is sensitive to ε_e
(slight ε_μ sensitivity comes through G_F)

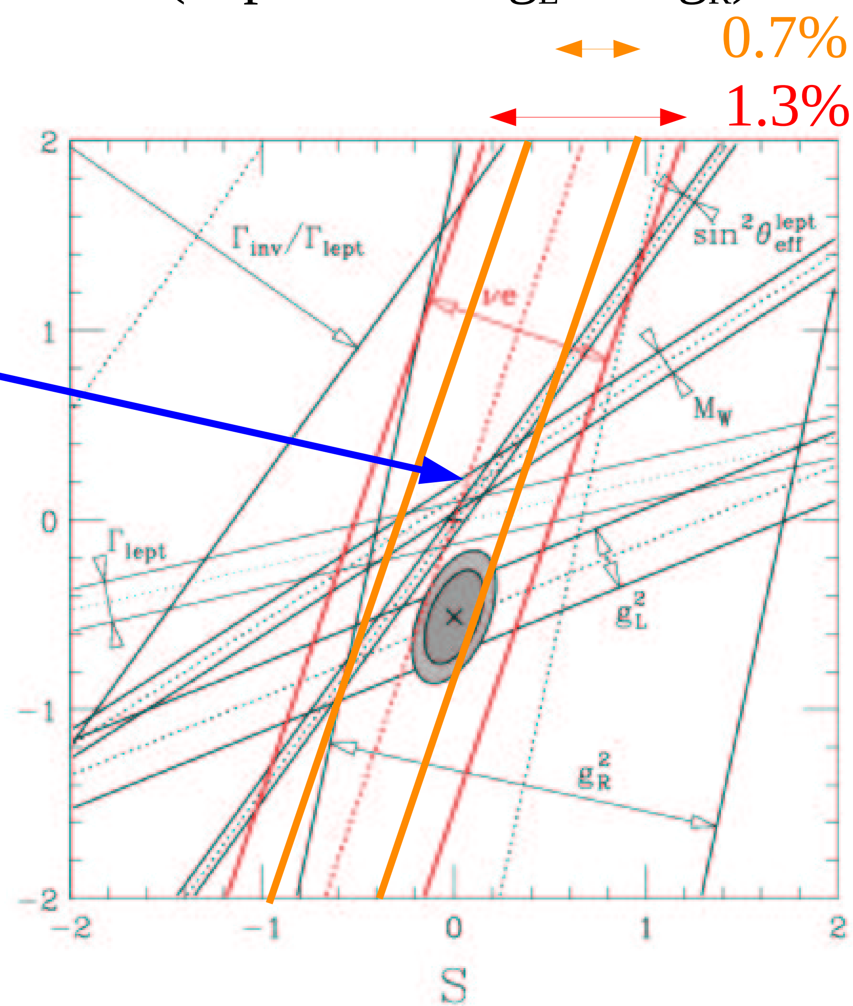
Plot by Loinaz, Fisher & Takeuchi...

Sensitivity to S & T in a model with nonzero-ε

Include NuTeV in the fit (expressed as g_L and g_R)

Solution without NuTeV is about here.

Downward shift is consistent with a heavy Higgs



Plot by
Loinaz, Fisher & Takeuchi...

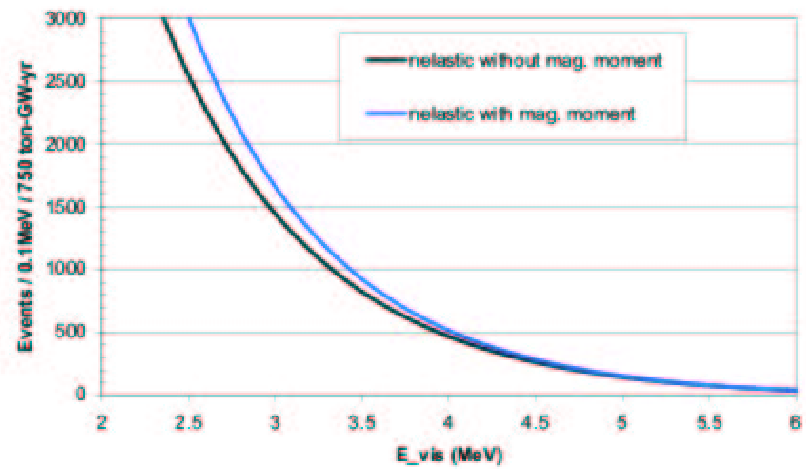
Sensitivity to a neutrino magnetic moment

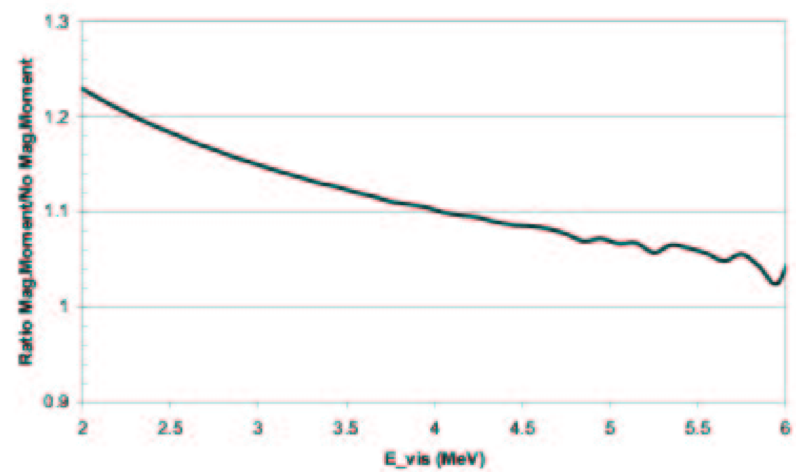
(Not cause of NuTeV anomaly!)

Neutrino magnetic moment:

A dN/N ~ 1% in agreement w/
SM would set a limit
×3 better than present lab limit

A analysis using the Evis
shape will improve this
sensitivity further
(requires good model of backgrounds
as function of Evis ... underway)

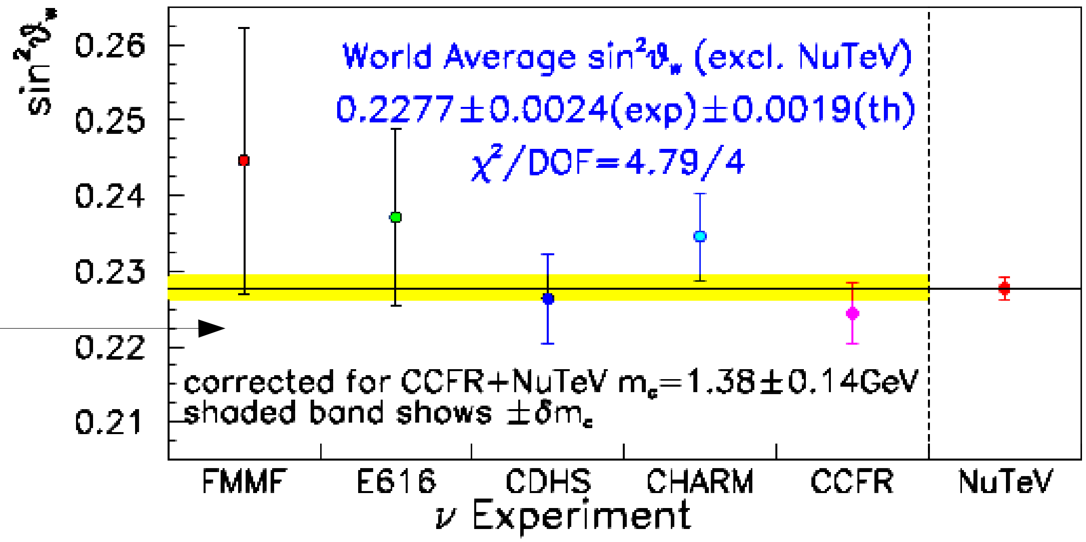




Sensitivity to neutrino-sector surprises...

NuTeVagrees with other DIS ν measurements, but with much smaller errors...

SM=0.2227



Maybe the effect isn't anything we have thought of...

A new <u>neutrino</u> experiment, that is <u>not DIS</u>,
that sees the same effect
would <u>definitely be interesting</u>!

Some thoughts...

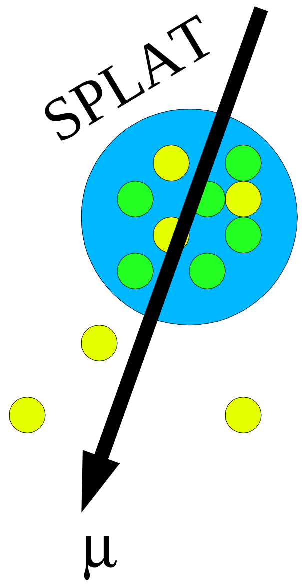
Type of BSM Physics	Value/Uniqueness of info
Z-prime	So-so
S and T studies	Good
Nonstandard Couplings (ε_e)	Very Good
Magnetic Moment	Very Good
NuTeV Surprise	Excellent

Reality Checks:

How do you measure ES at a reactor-experiment to ~1%   ???

1. The reactor flux is only known to 2%

2. This is a single-electron signal (unlike inverse beta decay)
   Potential backgrounds are:
   beta-decaying contaminants
   spallation-produced isotopes.

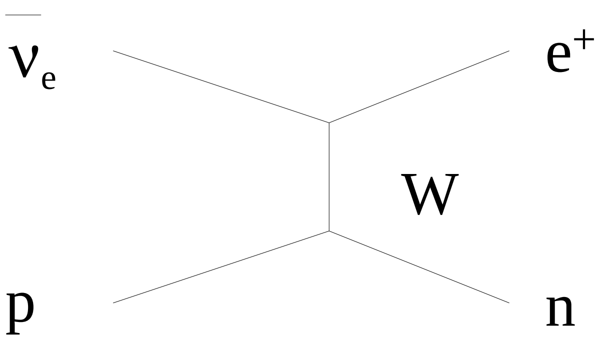


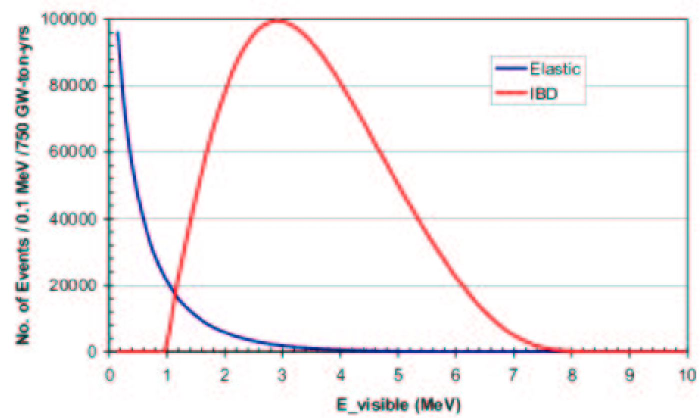
3. The energy scale must be calibrated to 0.5%
   (same level as NuTeV)

How are these going to be solved?

Tricks to make a precision measurement possible:

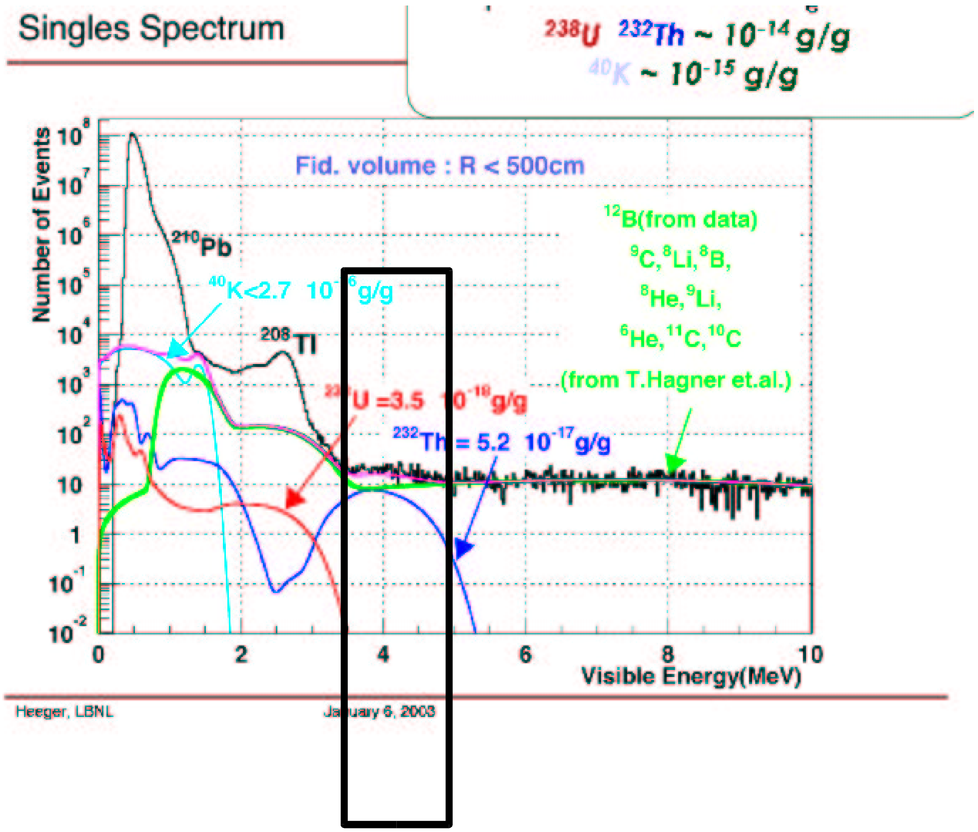
1. Remove the reactor flux uncertainty by normalizing to inverse beta decay (IBD)





This cross section is known to 0.2%

2. Use the window from 3.5-5 MeV to reduce backgrounds



Contamination:
Employ techniques for
Th clean-up from Borexino

Spallation
Go deep!
Measure the rate
w/ the far detector
& w/ VSPLAT

We have looked at many other potential systematic issues!

3. Use many beta sources to calibrate the detector:
cosmic-ray produced: muon decay, ^{12}B
naturally in the oil: ^{14}C
sources introduced into the oil

Summary:

Elastic scattering at a reactor can open new windows on the NuTeV anomaly and BSM physics

There are a number of locations where the experiment can be done. (Site-selection for θ_{13} experiment in progress.) Cost is low.

There are a lot of experimental issues to still be worked out.

We would love your feedback on this idea!

Thanks!

See also...

hep-ex/0403048

http://mwtheta13.uchicago.edu/index.html

http://faculty.washington.edu/josephf/beyond_theta13.html